CERTIFICATION AND PERFORMANCE EVALUATION PROCEDURES FOR DIESEL ENGINES AND EXHAUST TREATMENT SYSTEMS FOR COAL AND/OR NON-GASSY MINES

1.0 INTRODUCTION

1.1 PURPOSE

The Diesel Emissions Laboratory is an accredited facility within the CANMET Mining and Mineral Sciences Laboratories (MMSL), which is a division of Natural Resources Canada (NRCan), a department of the Government of Canada.

This document provides administrative information related to the Diesel Emissions Laboratory's testing and approval of diesel engines and exhaust treatment devices for use in underground mines. As such it covers the requirements for testing in both coal and non-gassy mines plus other confined spaces such as tunnels.

The exhaust gas emissions produced by diesel engines can be dangerous to human health. To ensure that worker exposure to these gases/particulate is within accepted limits, the exhaust can either be diluted with "fresh" air down to suitable concentrations or treated to remove a gas or particulate. Accordingly, this document describes the approval and testing procedures for the definition of toxic emissions from such equipment, and the corresponding minimum ventilation rate required to maintain a suitable air quality in the work place.

1.2 DEFINITIONS

1.2.1 Applicant means the manufacturer responsible for the final assembly and completion of a component or sub-assembly that is ready in every respect for marketing, and for which approval is sought.

1.2.2 Certificate, Equipment, means the document issued by CANMET-MMSL that indicates that a mining machine has been investigated and, when constructed and implemented in accordance with the provisions of the associated schedule is deemed to comply with the provisions of the requirements of the related standard(s).

1.2.3 Certification Officer means that Officer of CANMET-MMSL empowered by an Order-in-Council to investigate and approve diesel machines.

1.2.4 Supervisor means that Officer who supervises the Diesel Emissions Laboratory of CANMET-MMSL (see Clause 2.1.1 below).

1.2.5 Performance, Memorandum of, means the report of the Supervisor, describing the results of the testing of an exhaust treatment system when that system is not part of an "approved" engine/system package (see Clause 1.3.2.d below).

1.2.6 Approval, Memorandum of, means the document issued by CANMET-MMSL that indicates that an engine has been investigated in accordance with the pertinent engine emissions clauses of the related standard(s) and found to be suitable for use in mines.

1.2.7 Approval Plate means the metal plate displaying the NRCan's approval information pertinent to the equipment tested. Prominent display of this plate on the machine into which this approved equipment is to be installed is necessary for the approval to remain valid**.**

1.2.8 Rejection, Letter of, means the document issued by the Supervisor indicating that investigation of the engine or equipment for which approval is sought has shown that its performance is not in accordance with this document and the related standard(s), and that it is therefore not suitable for use in mines and tunnels.

1.3 SCOPE

1.3.1 Federal/Provincial Authority: Approval and/or testing by the Federal Authority signifies only that the equipment tested complies with the requirements set forth in this document, and the related standard(s) and test procedure(s). This Approval for the circumstances investigated, may be used by the mines inspection authority having jurisdiction as a contributing basis for permitting the approved equipment, and the machine in which it is installed, to be used underground.

1.3.2 Types of Services Provided:

(a) **Certification**: After satisfactory completion of the procedures described in CSA Standards M424.1 and 2, the Certification Officer will issue a certificate signifying that an entire mining machine adheres to the requirements therein, and, as such, is suitable for service in underground mines. This service is not described in this document (please refer to Standards CAN/CSA M424.1-88 and M424.2-M90, as in Section 3.1.1 below).

(b) **Approval**: Investigations of diesel engines with and without exhaust treatment devices (including: catalytic purifiers, total exhaust filters, exhaust diluters, and fuel additives), will be carried out at the request of the manufacturer. The equipment will be assessed in accordance with the pertinent clauses of the related standards CAN/CSA M424.2-M90 and M424.1-88 (or revised versions), describing the certification of diesel machines for Canadian mines. Equipment in compliance will then be issued a Memorandum of Approval indicating that the engine tested is suitable for the intended use.

(c) **Contracted Studies**: Exhaust emissions research under contract, or in connection with an approval, verification or certification, may be undertaken by the Diesel Emissions Laboratory, subject to negotiations regarding cost, test procedures and the disclosure of results for the public benefit.

(d) **Exhaust Treatment System Performance Evaluation**: Such systems, not undergoing CANMET-MMSL certification or approval, will be tested in accordance with the MAnufacturer's ProTocol for Exhaust Systems Testing (MAPTEST), as referenced below in section 3.1.2, or other national or international standards. A test report by the Supervisor indicating compliance with the test protocol will be provided.

2.0 GENERAL REQUIREMENTS

2.1 PROCEDURES

2.1.1 Application: The applicants, or their representatives, should consult with:

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Chief, Diesel Emissions
CANMET Mining and Mineral Sciences Laboratories
Minerals and Metals Sector
Natural Resources Canada
555 Booth Street, BCC Bldg. #9
Ottawa, Ontario, Canada K1A 0G1
Tel: (613) 996-6103
Fax: (613) 996-2597
E-mail: mgangal@nrcan.gc.ca

in order to discuss equipment testing, approval, certification, verification, evaluation, scheduling, costs and research requirements.

The location of the Diesel Emissions Laboratory and the shipping directions for equipment is:

CANMET Mining and Mineral Sciences Laboratories
Minerals and Metals Sector
Natural Resources Canada
Bells Corners Complex, Bldg. #9
1 Haanel Drive
Ottawa, Ontario, Canada K1A 1M1

(a) Application for testing and approval of diesel equipment for CANMET-MMSL certification can be made on company letterhead (see example of Appendix 1).

(b) The application for equipment approval can be completed by either the manufacturer or his/her agent and submitted along with a filing fee of Can$500 payable to the Receiver General for Canada. The equipment must be in a final, developed state, and ready for marketing.

(c) The Supervisor will discuss the testing requirements with the Applicant and will arrange for a service contract with terms and conditions prior to any testing. The engine dynamometer coupling hookup requirements are given in Appendix 4.

d) The equipment to be tested will then be shipped, prepaid FOB by the Applicant, to the shipping address given in Clause 2.1.1 above. The engine submitted for testing shall be pre-run by the Applicant to the extent required to allow it to be operated immediately at full load and speed at the laboratory. The extent of the equipment that must be shipped for testing will be determined by the Supervisor in consultation with the Applicant.

2.1.2 Tests and Reports

(a) All, or the major portion of testing of the equipment, will be performed in the Diesel Emissions Laboratory in Ottawa. With the approval of the Supervisor, some tests may be performed in the field or at the manufacturer's facility for the convenience of, and at the expense of, the Applicant.

(b) The tests to be performed are defined below in Clause 3.0.

(c) The timing of tests, the presence of witnesses, and the presence of members of the Applicant's technical staff required for assistance in assembly or dis-assembly of equipment, are to be determined by consultation with the Supervisor.

(d) The results of such tests are classified "Industrial Confidential" and as such cannot be shared with any other party without the consent of the Applicant, except that where applicable, non-emissions test data related to the ventilation rate prescription, will be recorded in the approval ventilation rates and certificate and made available to the public.

(e) It should be noted that test reports when furnished to the Applicant, do not in themselves represent an Approval.

2.1.3 Approvals and Rejections

(a) After the documentation described below in Clause 2.2.1 has been submitted, and subsequent to a satisfactory outcome of all tests, the Certification Officer will issue to the Applicant a Memorandum of Approval (see Clause 1.2.2).

(b) The Supervisor will release to the Applicant, information in the form of reports and/or test data tabulations that result from the investigation, also as described below in Clause 2.2.2.

(c) Alternatively and where applicable, should the equipment submitted by the Applicant not conform to the requirements of the related standard(s), the Supervisor will forward a Letter of Rejection (see Clause 1.2.8 above) accompanied by a statement giving the reasons for rejection.

2.2 DOCUMENTATION

2.2.1 Documentation by Applicant

(a) **Application Form**: A completed Application Form with the requested information on the form shall be submitted (see Clause 2.1.1 above).

(b) **Documentation**: All items of documentation must be furnished by the Applicant to the Supervisor. A copy of the documentation will be kept on file at the Diesel Emissions Laboratory for reference.

(c) **Drawings and Manuals**: Such shall be furnished in accordance with the following requirements:

(1) **Diesel Engines:**

Each drawing, manual or document, as required below, should be clearly numbered and dated:

- engine performance curve and specifications sheet;
- overall engine outline, mounting arrangement and overall dimensions to scale;
- schematic drawing of the fuel delivery system and definition of the constituent items;
- manual defining the fuel delivery system and fuel rate adjustments;
- schematic drawing of the emergency engine shutdown system
- scale assembly drawing of the intake air system;
- scale assembly drawing of the exhaust gas system including the after-treatment device;
- refer to Appendix 2 for an itemized list of the required engine specifications and information.

(2) **Exhaust Treatment Systems:**

Because of the wide variation of exhaust treatment systems, the documentation required for exhaust treatment systems will be determined during the initial discussions between the Applicant and the Supervisor (see Clause 2.1.1).

2.2.2 Investigation Documentation Furnished

In summary, the following documentation will be furnished by the Certification Officer, or the Supervisor as the case may be, to the successful Applicant for equipment approval and/or testing:

(a) Memorandum of Approval,
(b) Memorandum of Performance,
(c) Test Data Report, and
(d) Letter of Rejection, if applicable, with reasons for the rejection.

2.3 FEES

2.3.1 Payment of Fees and Costs

(a) The application fee of Can$500 is a non-refundable credit that will, however, be deducted from the total fees assessed for the services performed. It will not be refunded should the application be withdrawn before the investigation has begun. The testing work will begin on receipt of the application fee and acceptance of the service contract.

(b) Fees are payable in Canadian funds by cheque, bank draft, money order or postal note.

(c) Charges to the Applicant for partially completed testing will be made based on the work completed regardless of the outcome of the tests.

(d) A proposal outlining the scope, costs, scheduling, terms and conditions for the work will be sent to the Applicant for approval prior to starting any work.

(e) All the shipping costs of the equipment to be approved or tested will be borne by the Applicant.

3.0 TECHNICAL SUMMARY

3.1 TESTING STANDARDS

3.1.1 Canadian National Standards

The technical requirements for approval or certification of underground mining diesel machinery are described in the following two Canadian Standards Association (CSA) documents:

- CAN/CSA Diesel Standard M424.1-88 for coal and other gassy mines,

- CAN/CSA Diesel Standard M424.2-M90 for non-gassy mines.

These National Standards of Canada, as approved by the Standards Council of Canada, may be obtained from:

The Canadian Standards Association (CSA)
5060 Spectrum Way
Mississauga, Ontario, Canada L4W 5N6
Tel: (416) 747-4000
Fax: (416) 747-2473

In addition, the fuel specification for emissions testing is contained in:

Canadian General Standards Board
Standard - Mining Diesel Fuel -
CAN/CGSB-3.16,

a copy of which may be obtained from:

The CGSB Sales Centre
Place du Portage Phase III
11 Laurier Street, 6B1
Gatineau, Quebec, Canada K1A 0S5
Tel: (819) 956-0425
Fax: (819) 956-5644

3.1.2 Manufacturers' Protocol for Exhaust Systems Testing (MAPTEST)

The requirements and test procedures are described in a document that was prepared by the members of the Diesel Exhaust Evaluation PROtocol Committee (DEEPROC), called the "MAnufacturer's ProTocol for Exhaust Systems Testing" (MAPTEST), Report No. MMSL 97-064, September 1997.

3.1.3 Other Standards

The Diesel Emissions Laboratory is fully equipped for emission testing of diesel engines and/or exhaust after-treatment systems using various other national and international standards. The Diesel Emissions Laboratory is registered to ISO 9002, and is accredited under ISO/IEC 17025 to perform some tests. More information is available from the address provided in Clause 2.1.1.

3.2 TECHNICAL PROCEDURES

Technical enquiries in general, and requests for answers to questions regarding this document or the related standards, should be directed to the Supervisor, as in Clause 2.1.1 above.

3.3 ENGINE EXHAUST EMISSIONS TESTING FOR CSA STANDARDS

For Dynamometer tests, engine test conditions and test-bed measurement methods are not described here but are similar to the ISO 8178-1 standard. The fuel employed in tests shall conform to CGSB standard 3.16 (see Clause 3.1.1) above. The CSA standard requires the following tests.

3.3.1 Worst Engine Operating Conditions: The CSA Standard requires a ventilation prescription pertaining to the operating conditions producing the greatest combined emissions toxicity.

3.3.2 Rapid Toxic Gas Search: To rapidly determine most polluting operating conditions, a preliminary series of short duration gaseous emissions tests for CO and NO_x are undertaken at various engine loads and speeds to cover the full design range of engine output. This testing determines the engine fail/pass condition, as described in Clause 3.3.3 below. If an engine fails, then no further tests are required.

3.3.3 Engine Fail/Pass Conditions: The CSA standards require that all the following conditions be met in order to obtain an engine approval. The undiluted exhaust gases shall contain not more than:

(a) 2500 ppm of carbon monoxide (CO),

(b) 1500 ppm of oxides of nitrogen (NO_X), and

(c) 150 mg/m^3 of particulate (DPM).

3.3.4 Steady-State Tests: To produce a suitable emissions map for the engine tested, complete emissions data are recorded at steady-state operating points covering the engine power and speed ranges. A minimum of four load points (100%, 75%, 50%, and 10% load) at five to six engine speeds under steady-state conditions are taken. These speeds are at: rated power, peak-torque, minimum speed with full load, speed with maximum NO_x, and other speeds to cover the entire engine operating range at the discretion of the supervisor. The other two mode points are at low and high idle speed with a minimum load.

3.3.5 Defining the Toxicity of the Exhaust Emissions:

For Canadian standards, the exhaust toxicity is determined using the EQI (reference).

The exhaust quality index (EQI) is determined from an equation quantifying the comprehensive toxicity of the emissions by incorporating the effects of several toxic gases and DPM, as follows:

$$EQI = \frac{CO}{50} + \frac{NO}{25} + \frac{DPM}{2} + 1.5\left[\frac{SO_2}{3} + \frac{DPM}{2}\right] + 1.2\left[\frac{NO_2}{3} + \frac{DPM}{2}\right]$$

Where,

CO - carbon monoxide, ppm
NO - nitric oxide, ppm
SO_2 - sulphur dioxide, ppm
NO_2 - nitrogen dioxide, ppm
DPM - diesel particulate matter, mg/m^3

3.3.6 Test Observations Recorded: An example Engine Test Summary Observation Sheet is provided in Appendix 3.

3.3.7 Major Test Equipment:

a) **Engine Parameters**: Intake air flow, fuel flow, engine speed and torque, various temperatures and pressures are measured.

b) **Exhaust Analysis**: An exhaust gas analysis cart is employed that incorporates gas sampling and analyzing functions, including: heated lines and cooling/drying equipment as required, as well as dry chemistry analytical equipment. The analytical methods employed for the major gaseous components are:

O_2	paramagnetic
CO_2	non-dispersive infrared (NDIR)
CO	non-dispersive infrared (NDIR)
SO_2	NDIR,or calculated value
NO	chemiluminescent CLD or HCLD with a NO_2/NO converter
NO_X	chemiluminescent CLD or HCLD with a NO_2/NO converter
HC	heated flame ionization (HFID)

c) **DPM Analysis**: The DPM sampling system includes heated sample lines and partial or full flow DPM systems.

3.3.8 Calibration Procedures: Each of the instruments for measuring the engine operating parameters and the exhaust emissions concentrations are calibrated using confirmed standards.

3.3.9 Coal Mine Related Tests will be performed injecting methane gas into the intake air in accordance with CSA Standard M424.1-88.

3.4 VENTILATION PRESCRIPTION

3.4.1 Ventilation Equation: Ventilation for an underground mine in which a diesel engine is emitting pollutants is derived from a weight balance involving the mixture produced from the blending of the exhaust gas and the ventilating air quantity. The ventilation equation is:

$$Q_{dva} = \frac{M_{dxg} \times EQI/3 + (0.09 \times H_2 - 1) \times M_f}{60 \times \rho}$$

Where,
Q_{dva} = the required flow of ventilation in scfm or m^3/min
M_{dxg} = the dry exhaust gas weight flow in lb/hr or kg/hr

EQI (see Clause 3.3.5 above)

H_2 = the percent by weight of hydrogen in fuel

M_f = the fuel consumption rate in lb/hr or kg/hr

ρ = the dry ventilation air density in lb/ft^3 or kg/m^3

The second numerator term being small can be neglected in the calculation.

3.4.2 Ventilation Tolerance: The ultimate ventilation prescription is rounded up to the next 100 scfm.

3.4.3 Ventilation Reductions for Site-Specific Conditions: The ventilation requirement for the most polluting engine operating conditions may be reduced for site-specific circumstances by the appropriate Regulatory Authority, and as stipulated in CAN/CSA M424.2-M90, Clause 5.4 - "Assessed Ventilation Recommendations." These recommended adjustments or reductions, include:

(a) Altitude Variations
(b) Ventilation Distribution Efficiency
(c) Machine Loading Cycle
(d) Multiple Machine Density
(e) Mine Layout
(f) Efficiency of Maintenance, and
(g) Use of Low-Sulphur Fuel.

Some items can be addressed during the approval processes, as follows:

Altitude Variations: Air density varies with altitude. Thus, while the fuel rate remains constant, increasing the altitude correspondingly decreases the air weight flow and makes the fuel/air mixture more fuel-rich. This potentially increases the toxicity of the emissions, invalidating the assessed ventilation rate at sea level. Thus, to maintain the validity of the prescribed ventilation rate, the fuel rate must be commensurately reduced, or the ventilation rate increased. As the former is more easily accomplished, the maximum fuel rate is usually reduced. The relative air density factor is the same as the fuel rate reduction factor. Table 1 below illustrates the possible variations.

Table 1 - Variation of Ventilation Factor with Altitude

altitude (ft)	fuel factor	ventilation factor
-6000	1.20	0.83
-4000	1.13	0.89
-2000	1.06	0.94
sea level	1.00	1.00
+2000	0.94	1.06
+4000	0.89	1.13

Consequently, the maximum allowable fuel rate or the prescribed ventilation rate will be adjusted in accordance with the above table for varying altitudes.

Machine Loading Cycle: The greatest comprehensive toxicity of emissions often occurs at full load/speed engine operating conditions. As underground machines infrequently operate at full load/speed, the maximum ventilation determined at such conditions may be reduced in practice. Machine loading cycle measurements suggest the following conservative factors for ventilation reduction from the prescribed maximum:

load-haul dump machines.. 0.85
ore haulage trucks..... 0.70
utility machines and
personnel carriers.... 0.50

These adjustments or reductions may be permitted by the appropriate Regulatory Authority to reduce ventilation rates, assuming individual concentrations of toxic constituents remain below their respective current threshold limit values (TLV).

Use of Low-Sulphur Fuel: CSA Standards M424.1 and .2, require emissions testing to be performed employing diesel fuel as

specified in the CGSB Mining Fuel Standard. This standard permits the use of diesel fuel at the mine site which contains a maximum of 0.5% sulphur by weight. However, some mining operations purchase premium fuel with a normal analysis of less than 0.05% sulphur.

The EQI expression (Section 3.3.5) rewards the use of lower sulphur fuels by proportional reductions in ventilation.

The engine Memorandum of Approval (Section 1.2.6) provides ventilation rates for various concentrations of sulphur in the fuel.

APPENDIX 1 - EXAMPLE OF APPLICATION FOR APPROVAL

Dr. Mahe Gangal
CANMET Mining and Mineral Sciences Laboratories
Natural Resources Canada
555 Booth Street, BCC Bldg. #9
Ottawa, Ontario, Canada K1A 0G1

date: _____

Enclosed please find a cheque for the required Can$500 application fee, made out to the Receiver General for Canada. It is understood that the fee is a non-refundable credit that will be deducted from the total fees ultimately assessed for the testing of our company's diesel-related equipment as described below in order to obtain approval for use in mines in Canada and other confined work locations.

The equipment to be investigated is defined by the following information:

Approval required for: gassy coal mines _____ or non-gassy mines _____
Type of device or assembly: _____
Manufacturer: _____
Model number: _____
Serial number: _____
Other:

The enclosed promotional literature further defines the equipment, its function, and its performance. Also enclosed are the engine performance curves and specifications sheet.

This application is submitted by:

Company name: _____
Address: _____
Tel.: _____ Fax: _____ e-mail: _____
Liaison officer: _____

Submitted by:

Signature: _____
Name: _____
Position: _____

APPENDIX 2 - DOCUMENTATION FOR APPROVAL OF A DIESEL ENGINE FOR NON-COAL MINE USE IN CANADA

ENGINE
- manufacturer.....
- model .....
- serial number .....
- number of parts manual.....
- number of repair manual.....
- IDI or DI.....
- number of cylinders.....
- cylinder arrangement .....
- flywheel size (see SAE J620 as guide).....
- engine flywheel housing flange no. (see SAE J617 as guide).....
- engine displacement.....
- compression ratio.....

- rated horsepower .....
- rated speed .....
- torque at rated speed.....
- fuel consumption at rated power .....
- maximum governed speed .....
- peak torque .....
- speed at peak torque .....
- fuel consumption at peak torque .....
- starting speed .....
- idle speed.....
- type of engine cooling.....
- cooling system installed.....
- current generator installed?.....
- manuf'r, type and serial #.....
- air compressor installed?.....
- manuf'r, type and serial #.....

- v-angle .....
- bore .....
- stroke .....
- connecting rod length .....
- oscillating mass per cylinder.....
- moment of inertia - primary part.....
- moment of inertia - secondary part.....
- dynamic stiffness .....
- damping factor .....
- engine damping factor .....
- engine damper (if used).....
- type.....

FUEL INJECTION SYSTEM
- injection pump manufacturer.....
  - type .....
  - model number .....
  - serial number.....
- from injection pump manual:
  - fuel injection timing .....
  - timing adjustment means.....
  - max fuel rate adjustment .....
  - sealing pump adjustments.....

AIR CLEANER (dry type only)
- manufacturer.....
- model number .....
- serial number .....
- intake restriction clean filter .....

EXHAUST SYSTEM
- ex pipe diameter .....
- ex max back pressure.....

EXHAUST TREATMENT (if installed)
- manufacturer.....
- type.....
- model number .....
- serial number .....
- inlet/exit connection definition.....

OTHER
- maximum operating altitude.....
- crank case breather exit directed away from air intake?.....

APPENDIX 3 - EXAMPLE ENGINE TEST OBSERVATION SHEET

- manufacturer
- engine model #
- cooling fan
- air filter
- exhaust treatment

Special Conditions:

test number

engine variables

speed	rpm
torque	lb/ft
power	bhp
fuel rate	lb/hr

air flow

Pbar	mm H_g
air temp	^oF
RH	%
measured air flow	lb/hr
engine displacement	in^3

exhaust gas analysis (dxg basis)

CO_2	%vol dry
O_2	%vol dry
CO	ppm
NO	ppm
NO_2	ppm
SO_2	ppm
HC	ppm

particulate analysis

dry exhaust gas flow	lb/hr
wet exhaust gas flow	lb/hr
DPM concentration	mg/m^3

ventilation

EQI	index
ventilation required	scfm dry air

intake/exhaust/engine variables

engine oil temp	^oF
intake air temp	^oF
exhaust gas temp	^oF
inlet restriction	"H_2O
exhaust pressure	"H_2O

APPENDIX 4 – ENGINE DYNAMOMETER HOOKUP REQUIREMENTS

To minimize the delay after the engine is received, flywheel drawings with accurate dimensions (diameter of an inset step; bolt circle, size, number, and location of bolt holes; location and height of the central boss, etc.) should be forwarded well in advance of the engine shipping date.

The Diesel Emissions Laboratory may request that the manufacturer supply a specified SAE flywheel bolt pattern required to mate to the selected coupling or have the manufacturer supply a suitable flywheel/coupling adaptor plate. At the request of the manufacturer, the Diesel Emissions Laboratory can arrange to have an appropriate flywheel adaptor fabricated through a local firm or Engineering and Technical Services (Natural Resources Canada) upon delivery of the engine.

Depending on the engine flywheel size and vibration damping requirement, the universal shaft and selected coupling can accommodate most flywheel configurations with an appropriate adaptor. All bolts connecting the shaft, viscous coupling, adapter plate and flywheels should be of minimum Grade 5 (SAE) or Grade 8.8 (ISO) and torqued to specification with a torque wrench.

Torsional Couplings

The Diesel Emissions Laboratory utilizes four torsionally flexible couplings in order to keep the main resonance speeds below the idling speed. The dynamometer drive shaft system is shown in Figure 1. Furthermore the couplings should provide a large damping capacity in order to keep vibrations at a minimum. The final determination of the suitable coupling demands carrying out provisionally a torsional vibration calculation based on previously requested engine data.

The four torsional couplings are designed for connection to universal joint shafts (UJS), which are insensitive to large bending angles of the UJS during normal operation (Figure 1). In general, the customer should use as a guide and provide a flywheel housing type that follows the SAE J617 Standard - Surface vehicle standard ® Engine flywheel housing and mating transmission housing flanges. This standard specifies the major dimensions and tolerances for Engine Flywheel Housings and the Mating Transmission Housing Flanges. The standard locates the crankshaft flange face or the transmission pilot bore (or pilot bearing bore) stop face in relation to the housing flange face. The four couplings are designed to work with a SAE J17 flywheel housing in limited configurations from SAE J617 No. 4 (361.5 mm), No. 3 (409.58 mm), No. 2 (447.68 mm), No. 1 (511.2 mm) and No. 0.5 (584.2 mm) nominal pilot dimension (A).

The four torsional couplings flanged face are designed against SAE J620 standard for flywheels with industrial engines with SAE J620 flange sizes No. 10 (314.3 mm), No. 11.5 (352.4 mm), No. 14 (466.7 mm) and No. 16 (517.5 mm) diameters. Typically but not limited to, each coupling can serve a certain engine power range as follows:

No. 10 (100 HP); No. 11.5 (100-250 HP); No. 14 (250 to 500 HP); and No. 16 (500-600 HP).

Upon review, the laboratory will determine what flywheel size is required for testing. Some engines may require a different flywheel housing size in order accommodate the best coupling with the appropriate flange size.

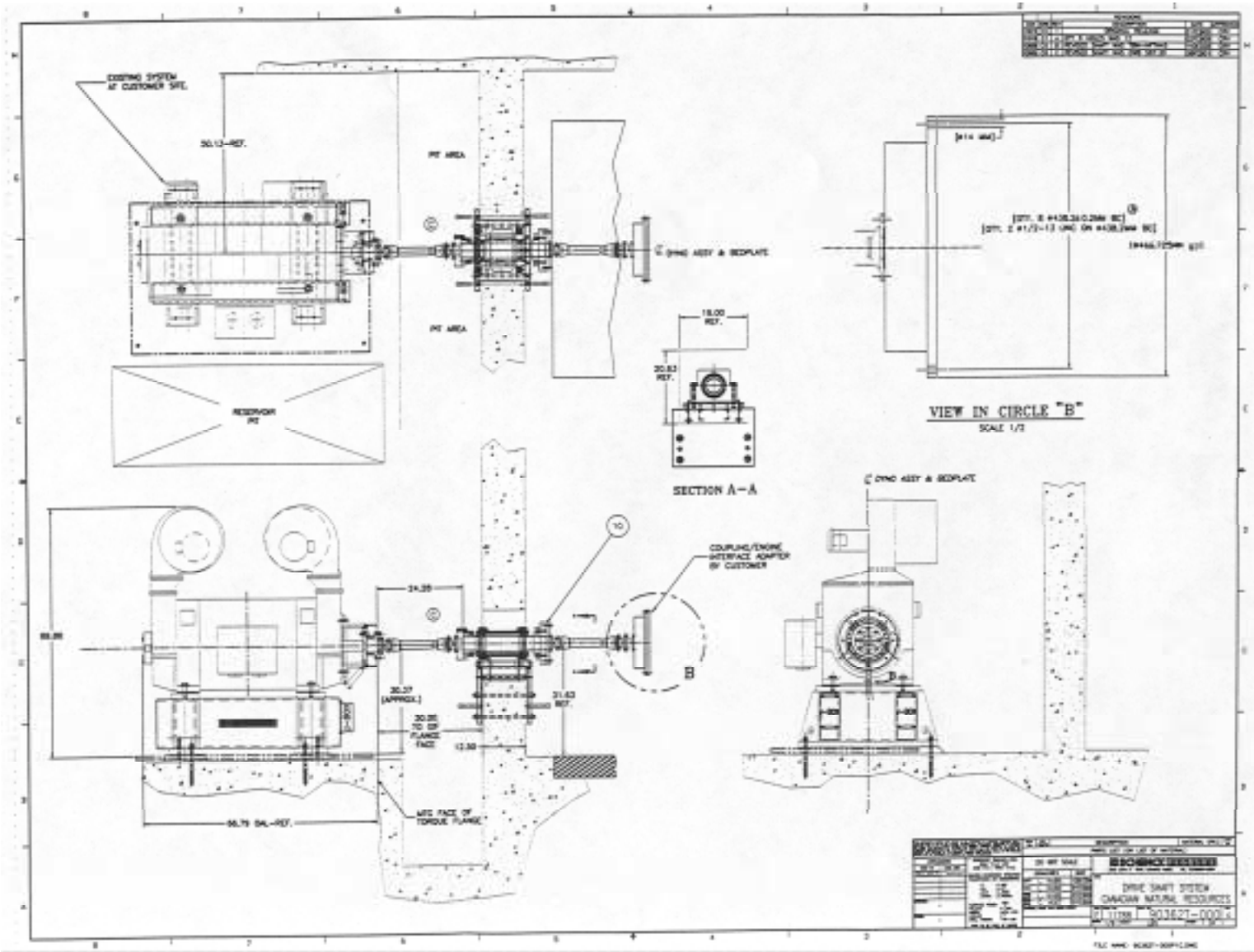

Figure 1. Drive Shaft System